BSC Earth Sciences Department

What

Environmental modelling and forecasting

Why

Our strength …
  … research …
  … operations …
  … services …
  … high resolution …

How

Develop a capability to model air quality processes from urban to global and the impacts on weather, health and ecosystems

Implement climate prediction system for subseasonal-to-decadal climate prediction

Develop user-oriented services that favour both technology transfer and adaptation

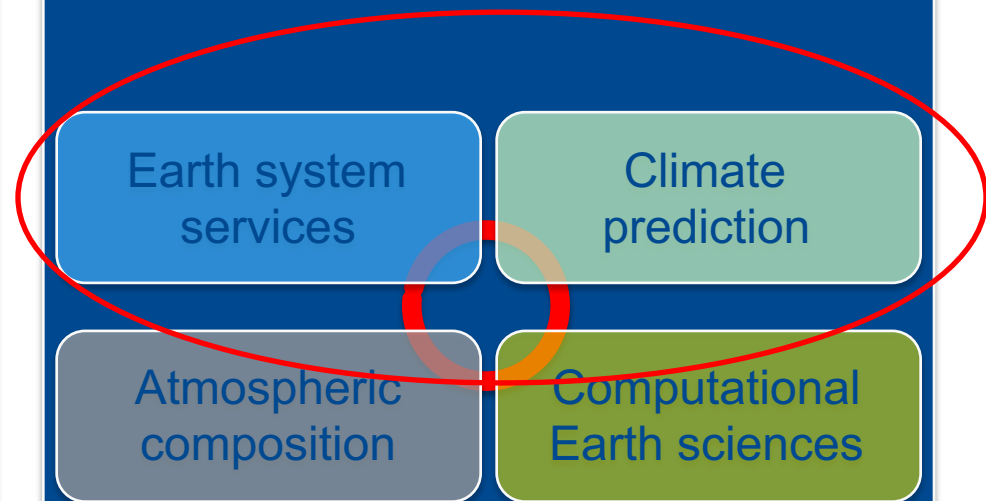Use cutting-edge HPC and Big Data technologies for the efficiency and user-friendliness of Earth system models
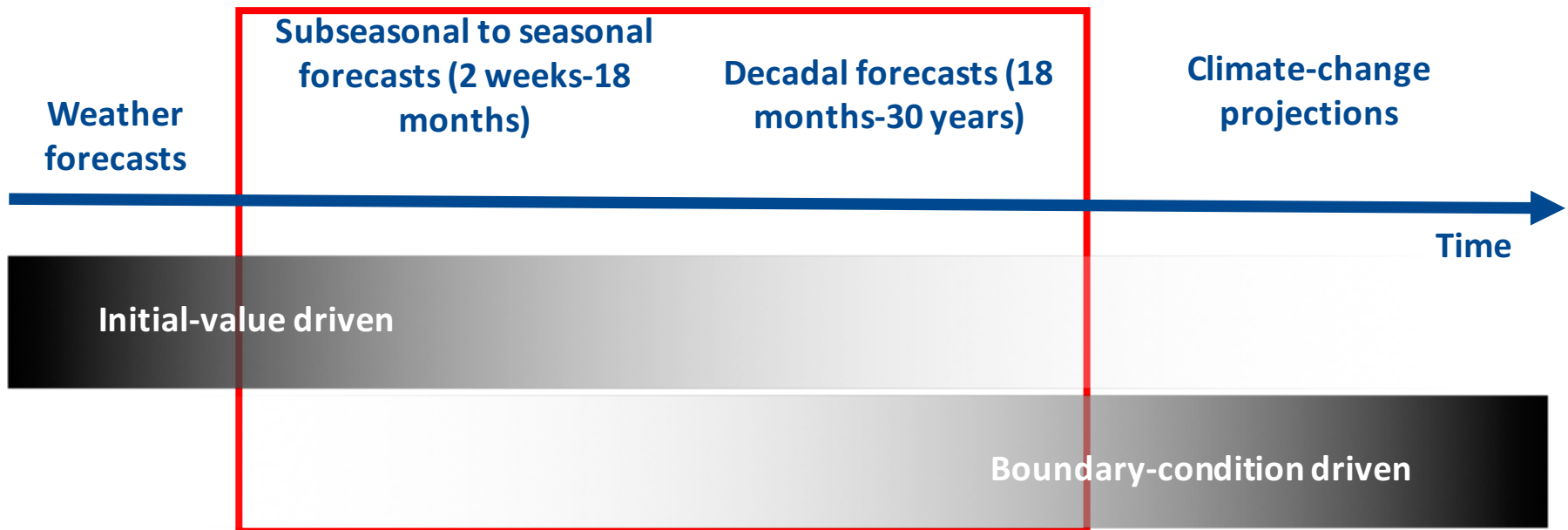
Earth system services

Climate prediction

Atmospheric composition

Computational Earth sciences

Climate prediction time scales
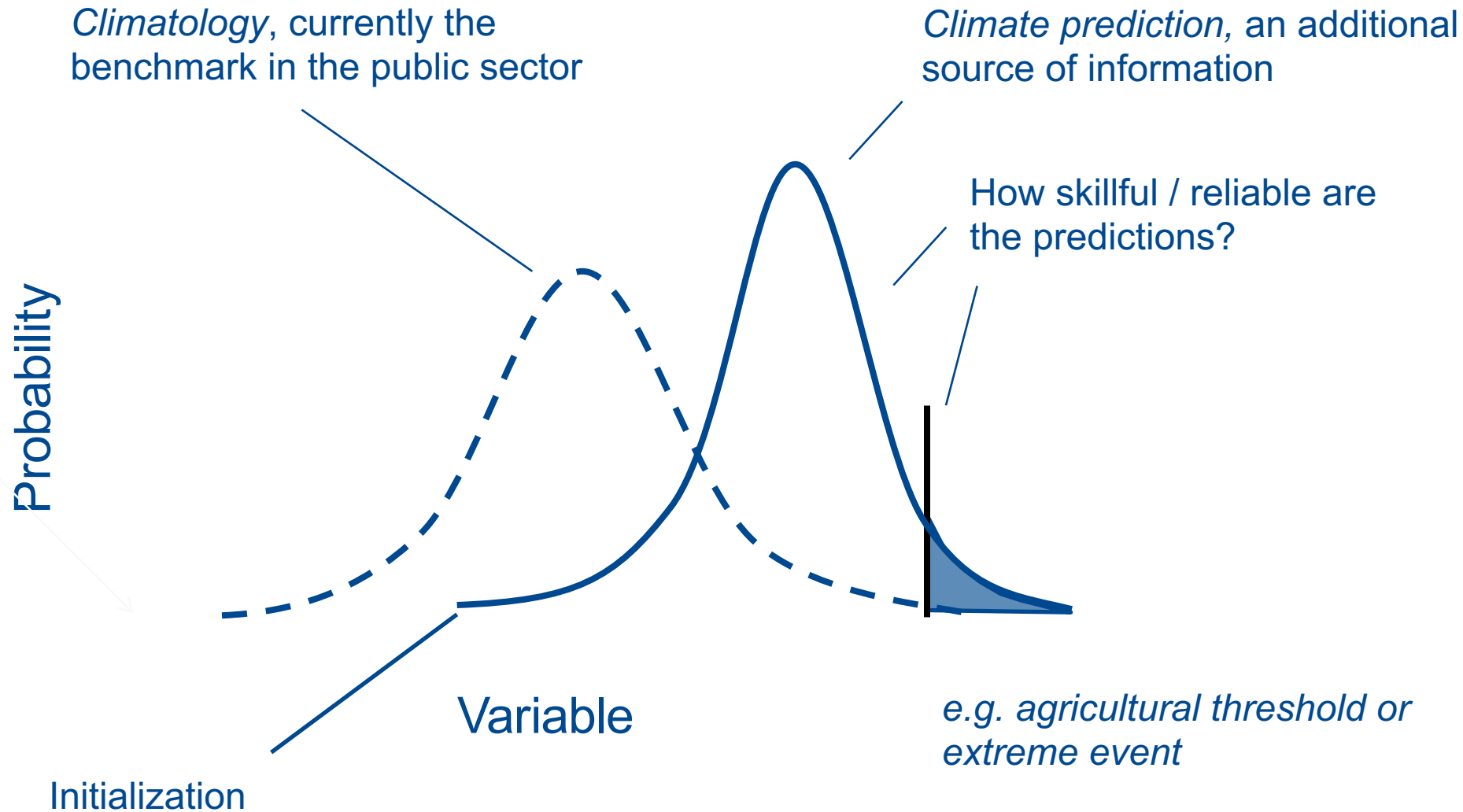
Between initial-value problems (weather forecasting) and multi-decadal to century projections as a forced boundary condition problem.

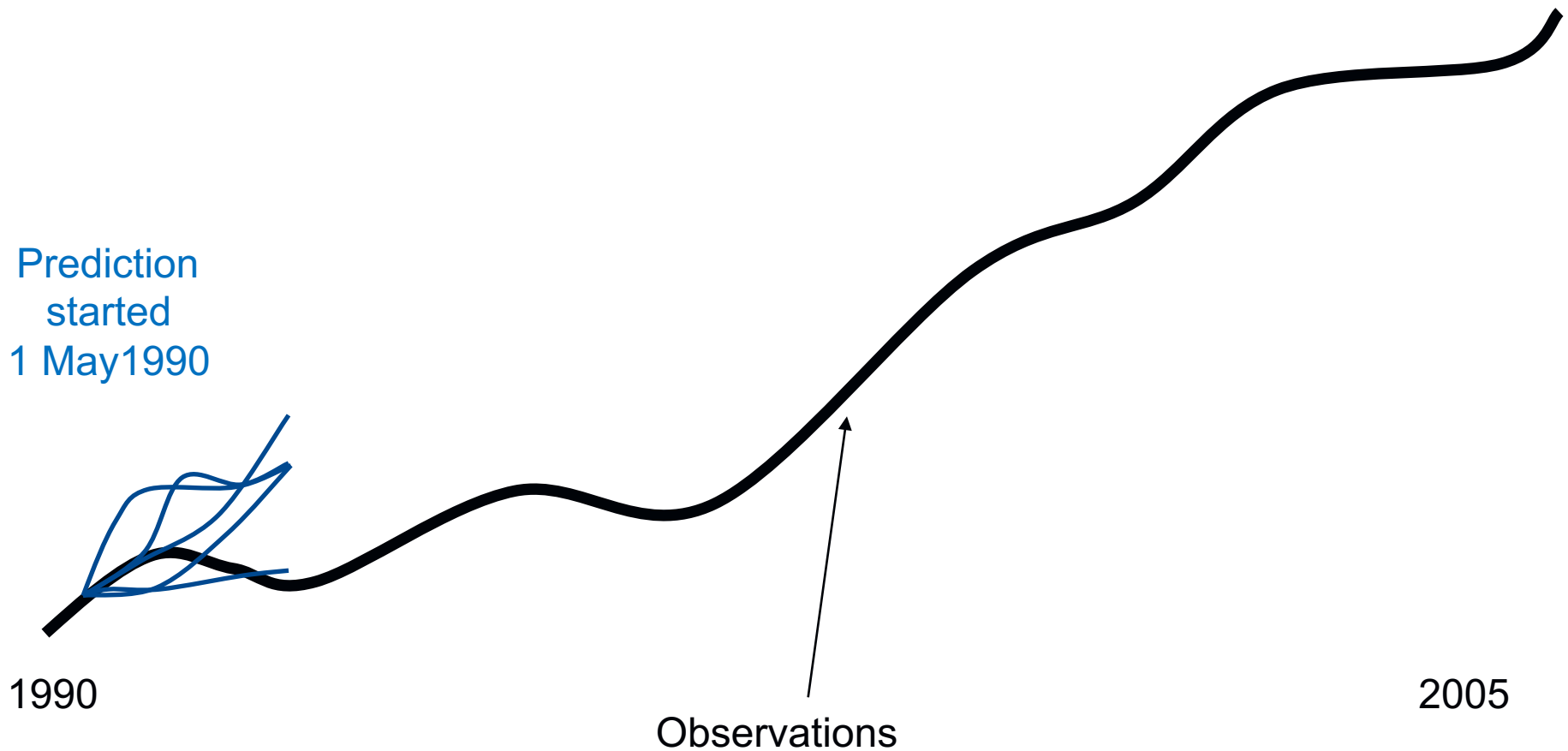Adapted from Meehl et al. (2009)

- Memory on interannual to centennial timescales in the ***ocean***

- Memory on seasonal to interannual timescales in the ***sea ice*** and ***land surface***

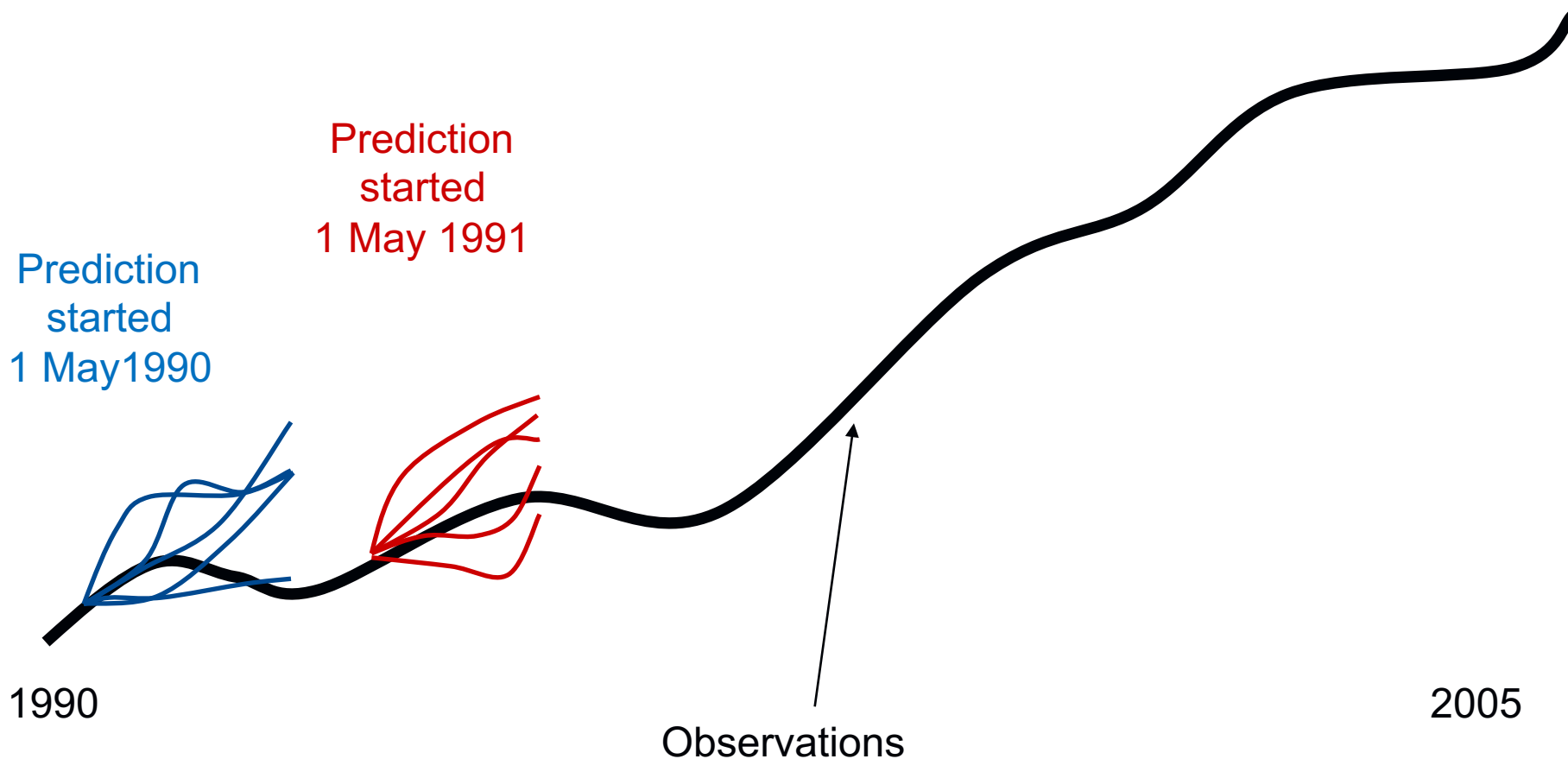- ***External radiative forcings*** (solar activity, greenhouse gases, aerosols)

Climatology, currently the benchmark in the public sector

Climate prediction, an additional source of information

How skillful / reliable are the predictions?

Probability

Variable

Initialization

e.g. agricultural threshold or extreme event

Prediction
started
1 May1990

1990

Observations

2005

Prediction started 1 May 1991

Prediction started 1 May1990

Observations

1990

2005

Prediction started 1 May 2005

Prediction started 1 May 1991

Prediction started 1 May 1992

… every year …

Prediction started 1 May1990

1990

Observations

2005

Prediction
started
1 May 2015

… every year …

Prediction
started
1 May 1992

Prediction
started
1 May 1991

Prediction
started
1 May1990

Focus on temporal averages e.g. year 2-5 for probabilistic forecasts

1960

Observations

2005

Prediction started
1 May 2005

Future: 5,500 simulated years
1.4 PB, 200 million core hours

Prediction started
1 May 1995

Prediction started
1 May 1991

… every year …

Prediction started
1 May1990

Compute ensemble mean, compute e.g. correlation

1960

2005

Modelling framework
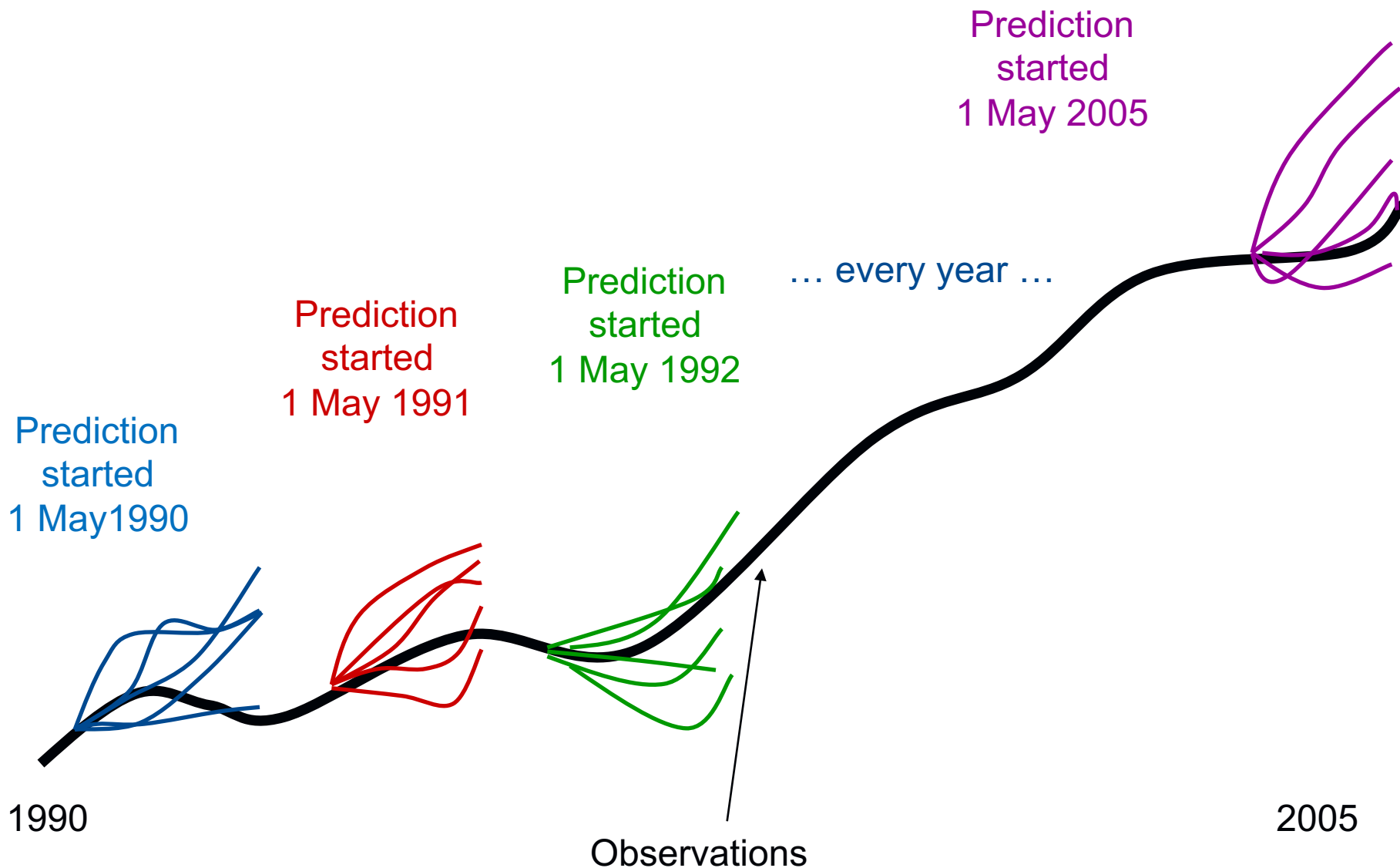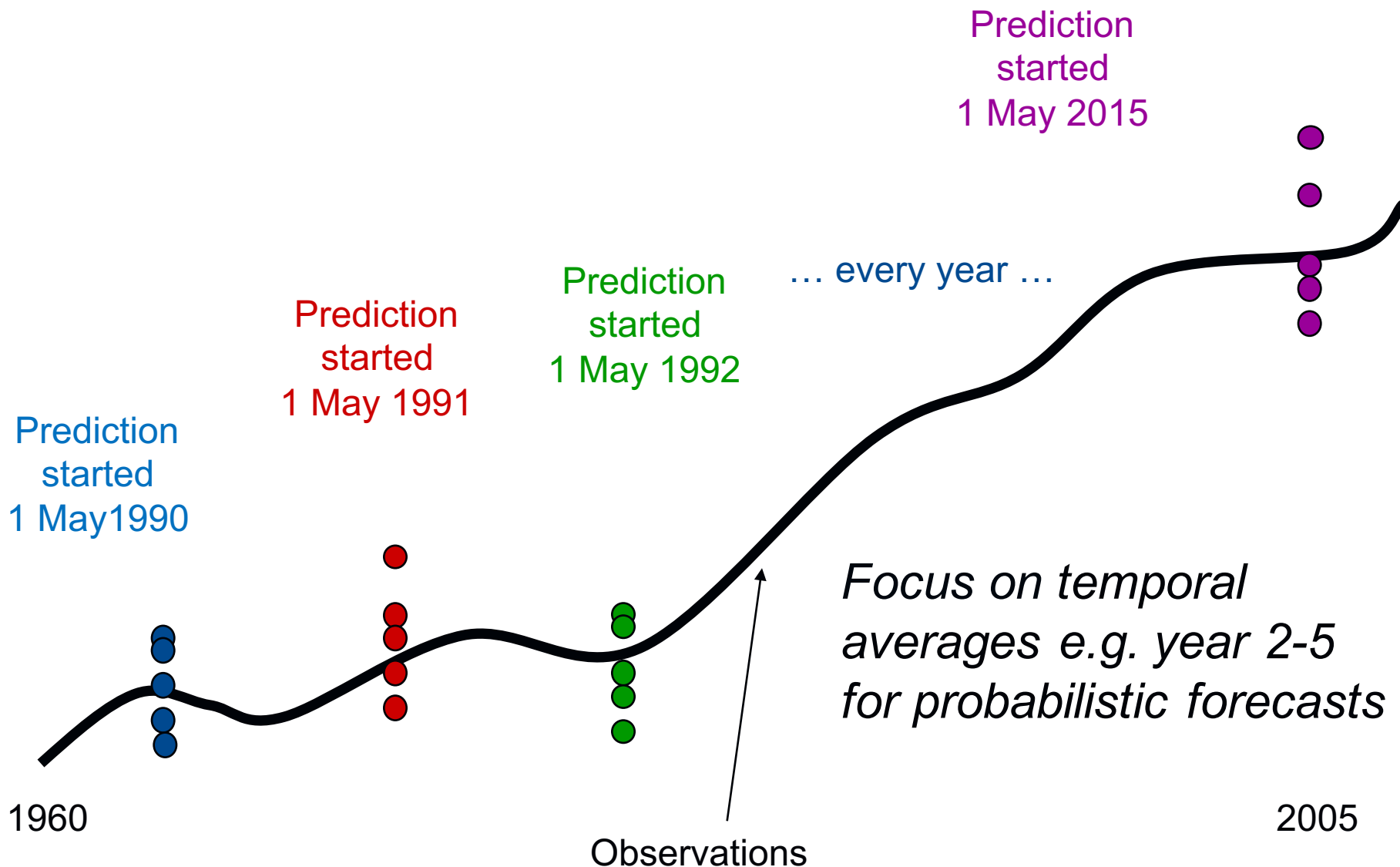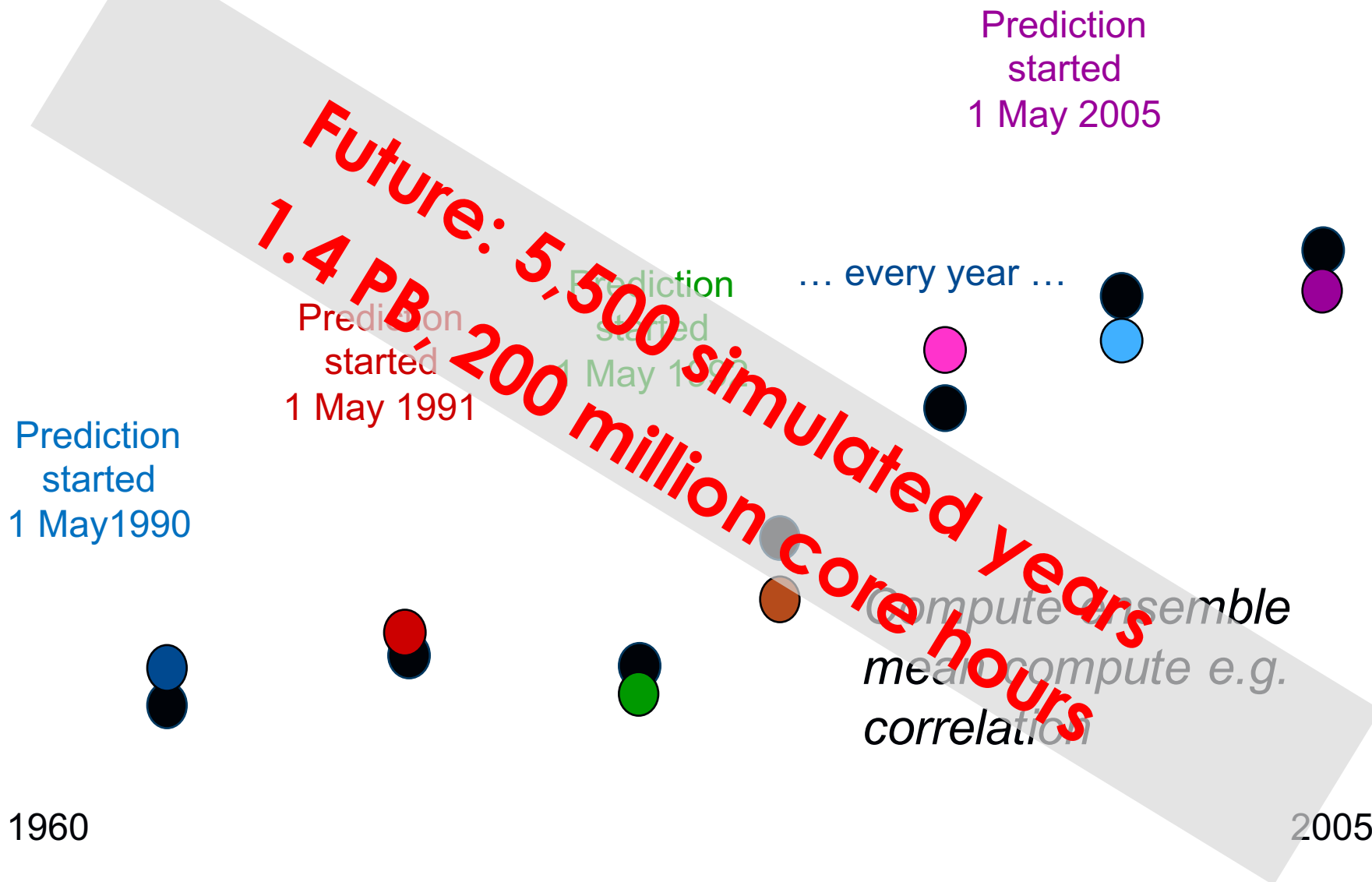
Standard resolution T255ORCA1

High-resolution T511ORCA0.25
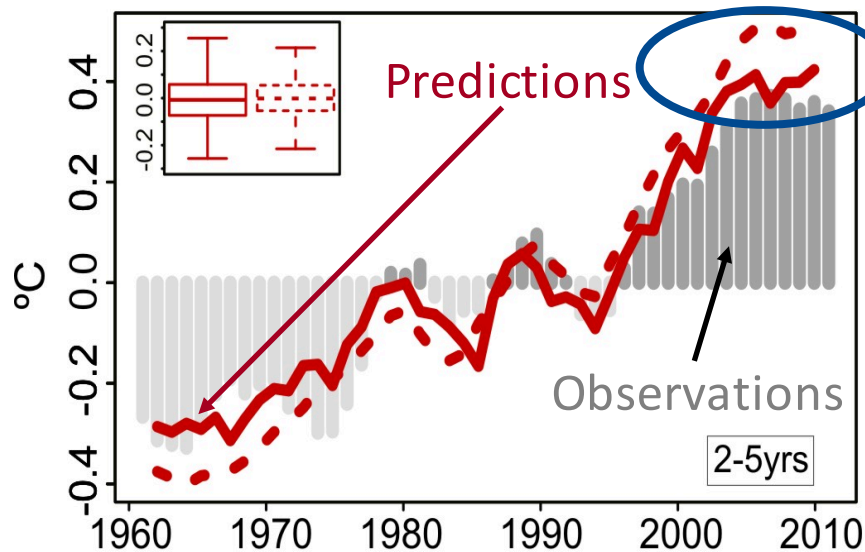~ 40 km atmosphere
~ 25 km ocean

Now testing T1279ORCA0.12
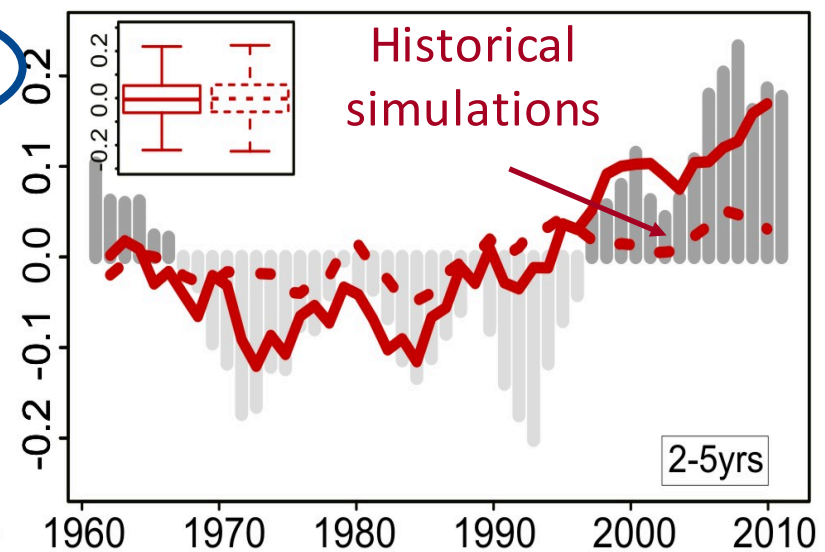~ 16 km atmosphere
~ 12 km ocean

Global-mean near-surface air temperature and AMV for forecast years 2-5

Global mean surface air temperature (GMST)

Atlantic multidecadal variability (AMV)

Initialised simulations reproduce the global temperature and some of the AMV tendencies and suggest that initialization corrects the forced model response and phases in internal variability.

Doblas-Reyes et al. 2013 (Nature Comm.)

Hurricane predictions

AMV is a decadal predictor for tropical cyclone activity in the Atlantic. Decadal predictions over forecast years 1-5.
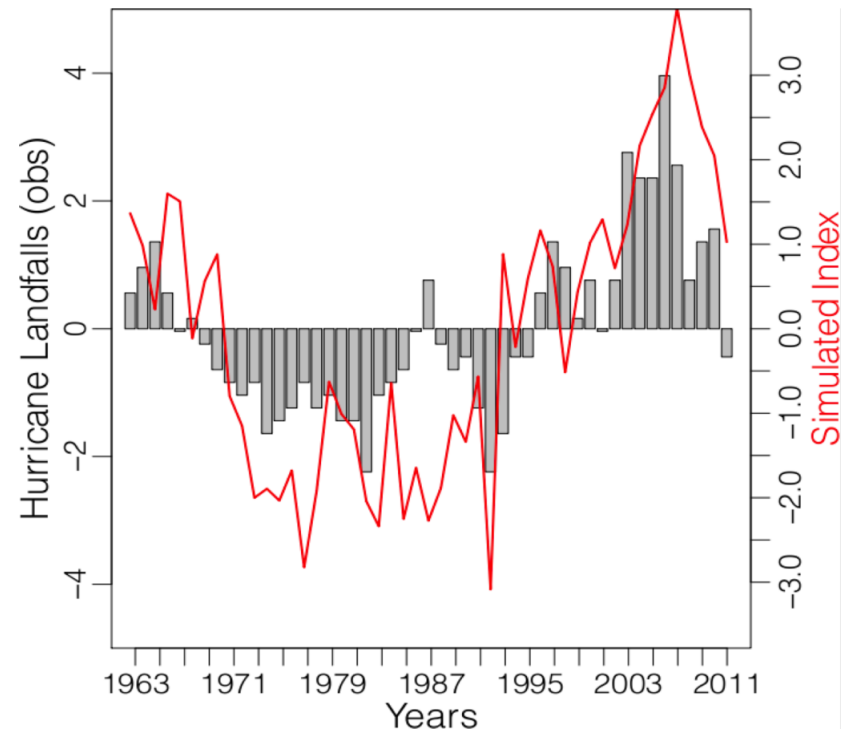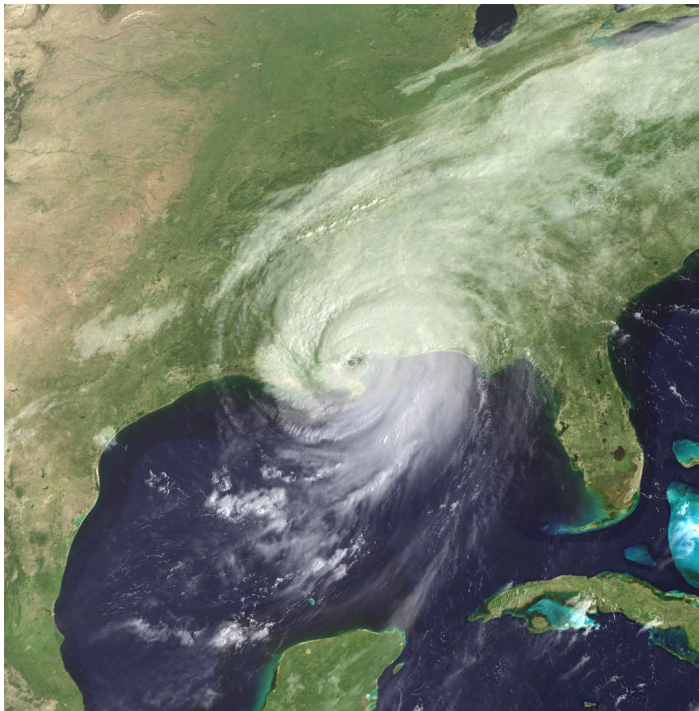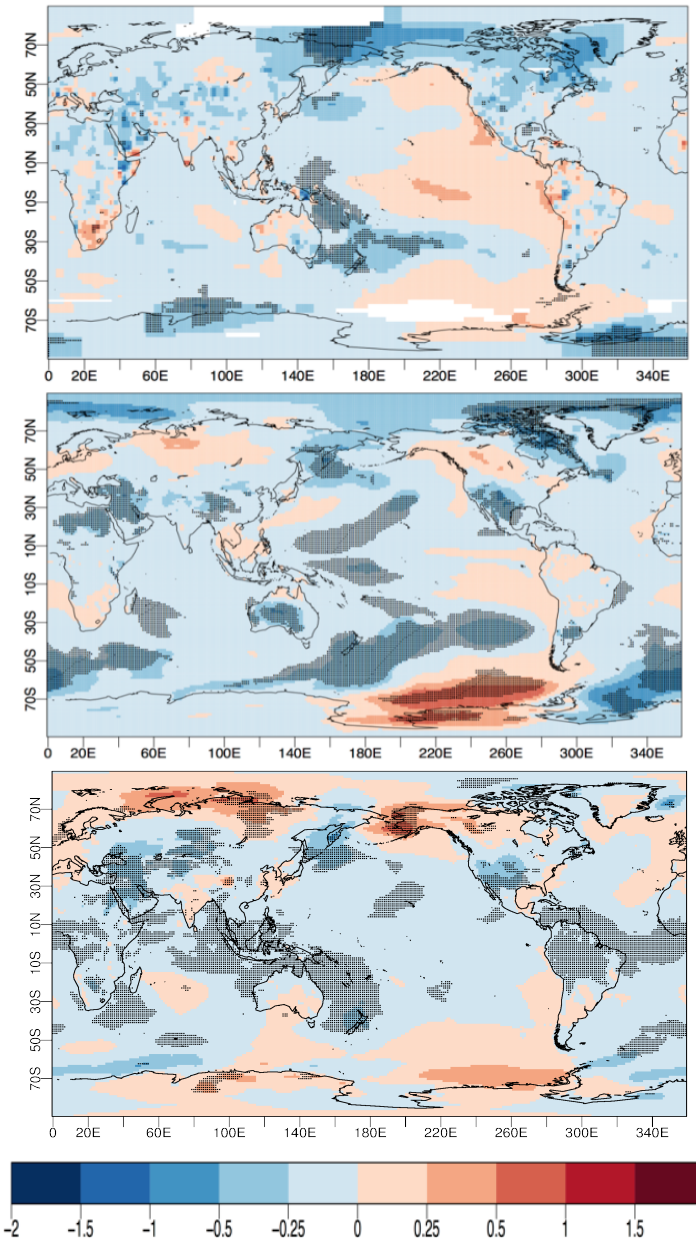
Surface temperature anomaly averaged over forecast years 1-3 averaged over forecasts initialized right before the Pinatubo, Agung and Chichon volcanic eruptions
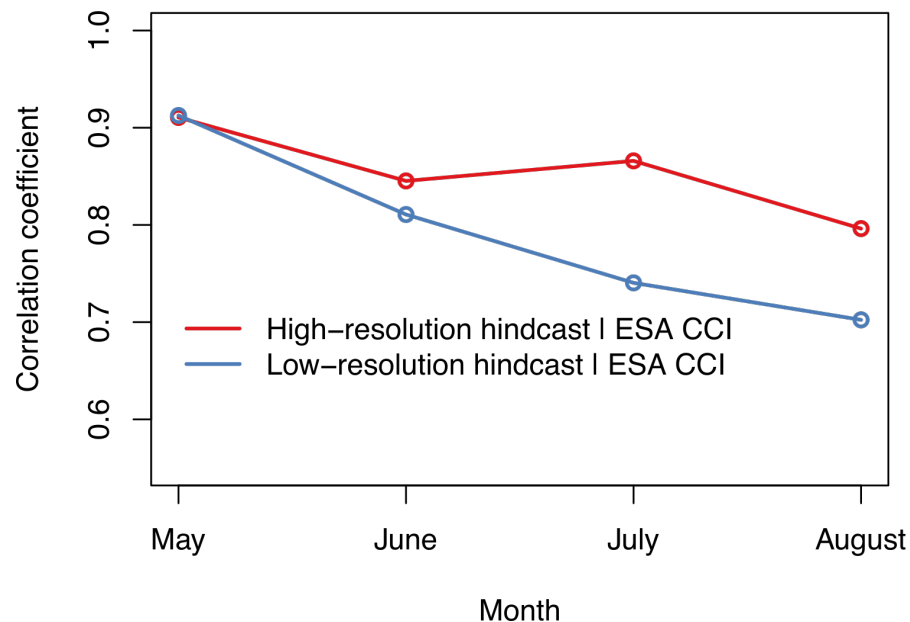
Observation

Hindcast using observed volcanic forcing

Forecast using idealized volcanic forcing

M. Ménégoz (BSC)

High horizontal resolution improves ENSO predictions.

Observational uncertainty similar magnitude as improvements.

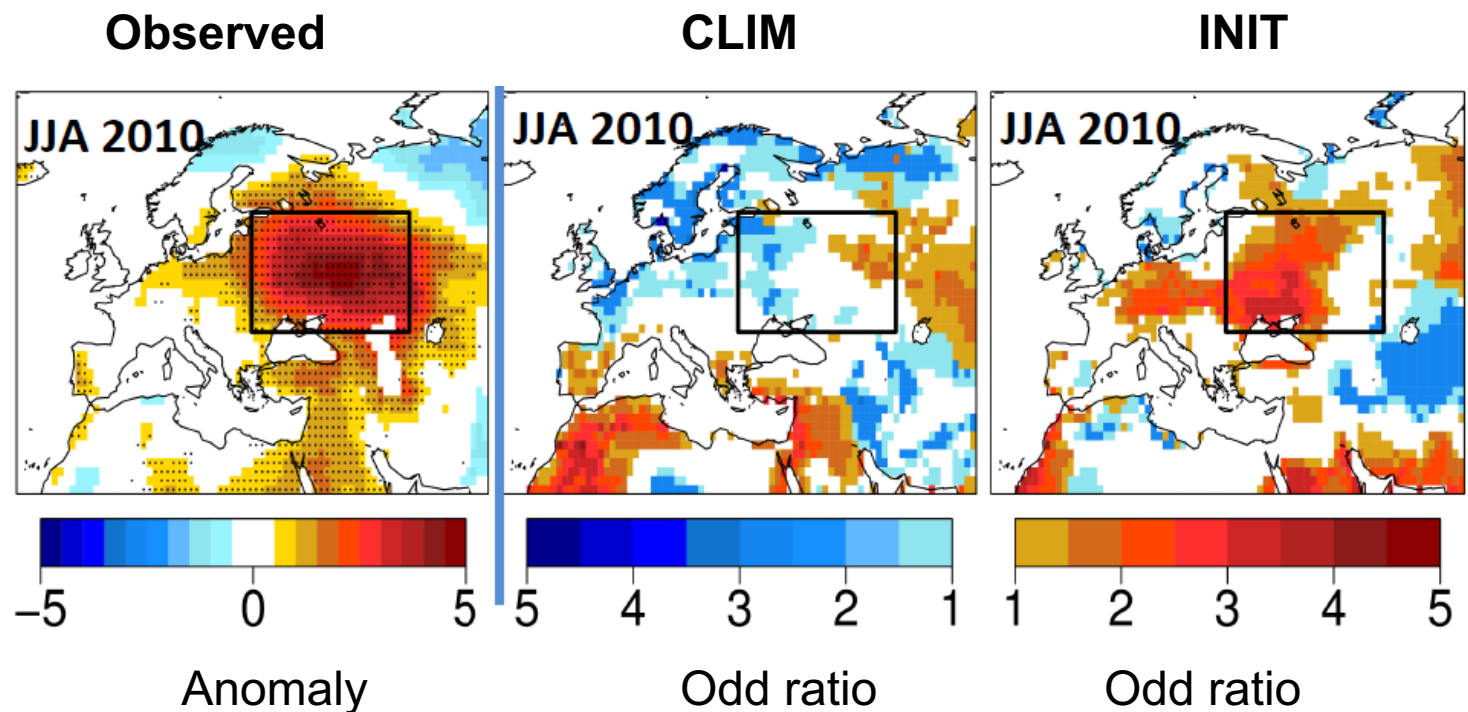Prediction skill ENSO: Increase in resolution

Difference in correlation
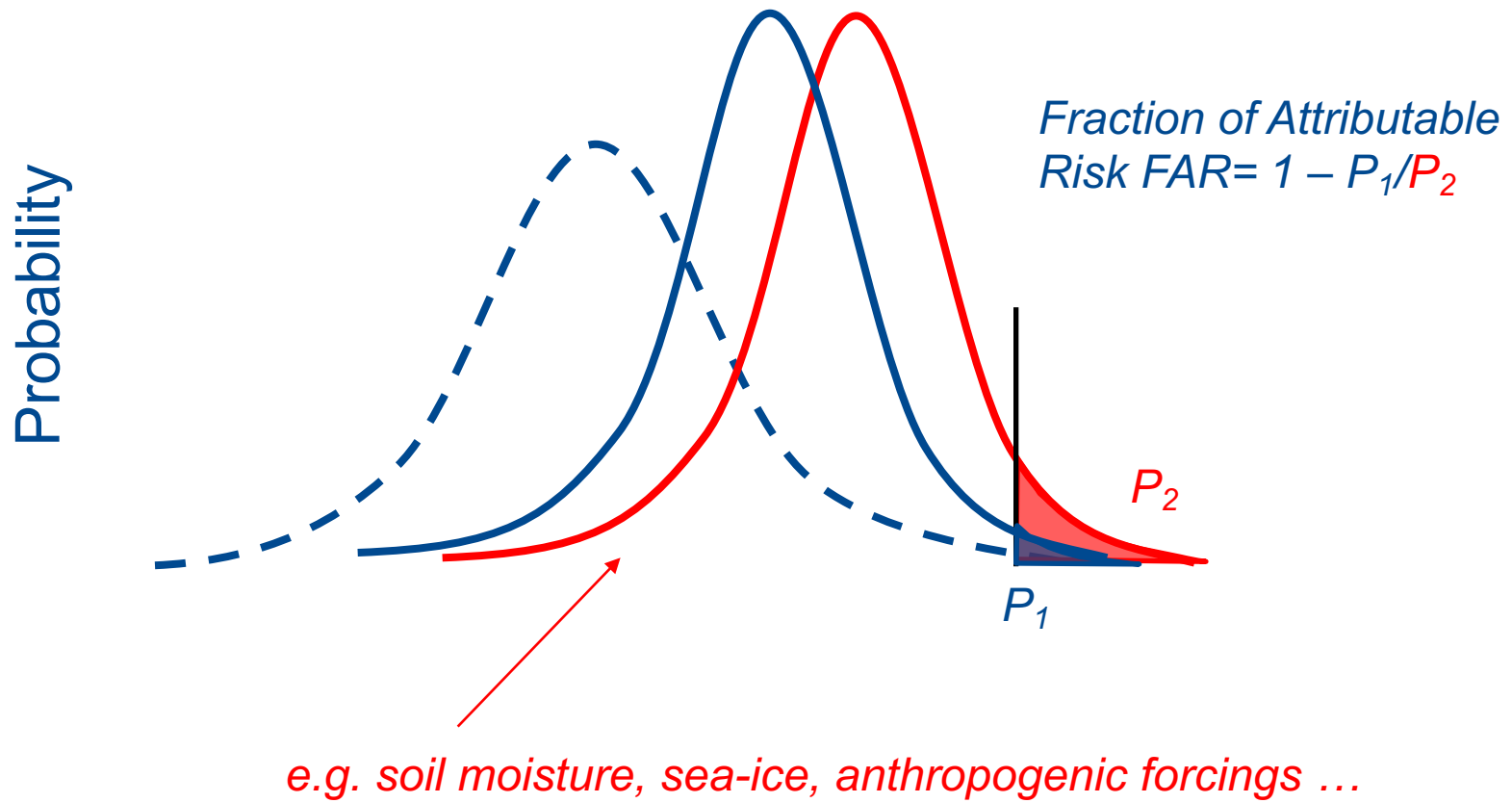surprisingly systematic

C. Prodhomme, O. Bellprat (BSC)

Seasonal climate forecasts initializing sea ice reconstruction (INIT) or a climatology of this reconstruction (CLIM). No impact on the atmosphere prediction skill

95% confidence interval
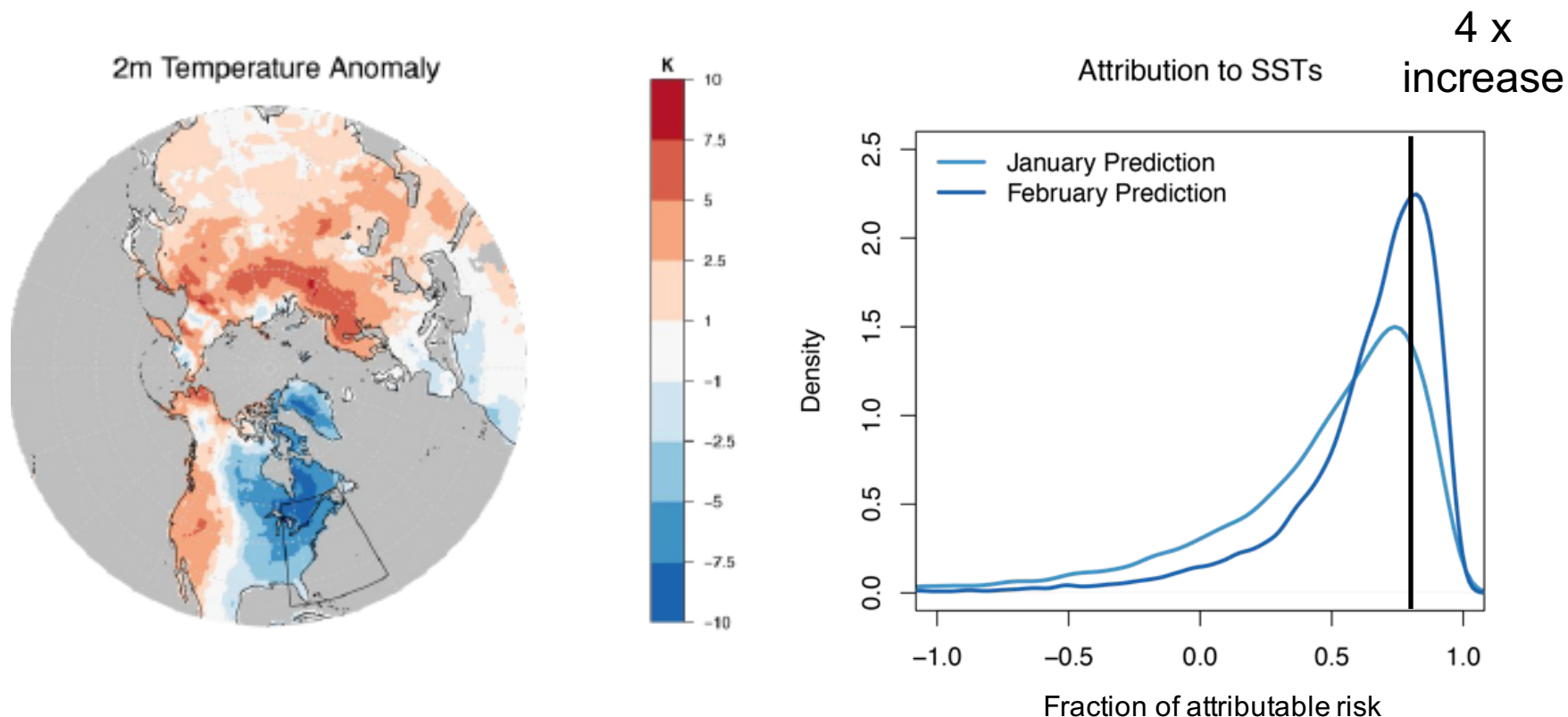
Beyond means: Extreme events
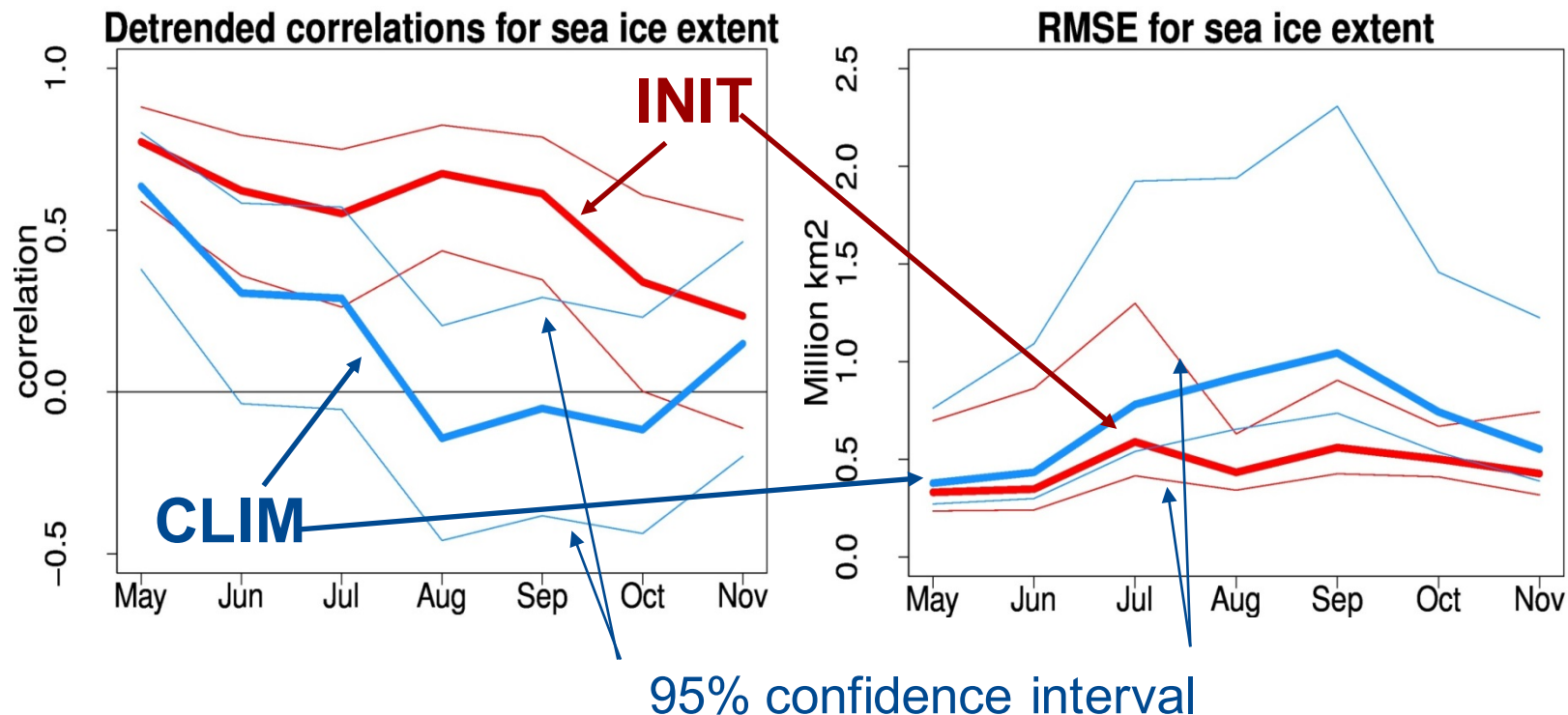
Seasonal prediction of Russian heat wave initializing observed land-surface (INIT) conditions and climatological (CLIM) conditions. Land-surface initialisation matters.

Observed	CLIM	INIT
Anomaly	Odd ratio	Odd ratio

How has the probability increased due to an external factor?

Fraction of Attributable Risk FAR= 1 – P_1/P_2

P_2

P_1

e.g. soil moisture, sea-ice, anthropogenic forcings …

Probability

Anomalous SST conditions favored the North American cold spell in 2015. Sea-ice (Arctic amplification) played no significant role.

2m Temperature Anomaly

4 x increase

Attribution to SSTs

January Prediction
February Prediction

Density

Fraction of attributable risk

A future climate service?

O. Bellprat (BSC)

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European climate services

Copernicus Climate Change Service (C3S)

C3S Vision

How is climate changing?
- Earth observations
- Reanalysis

Will climate change continue/accelerate?
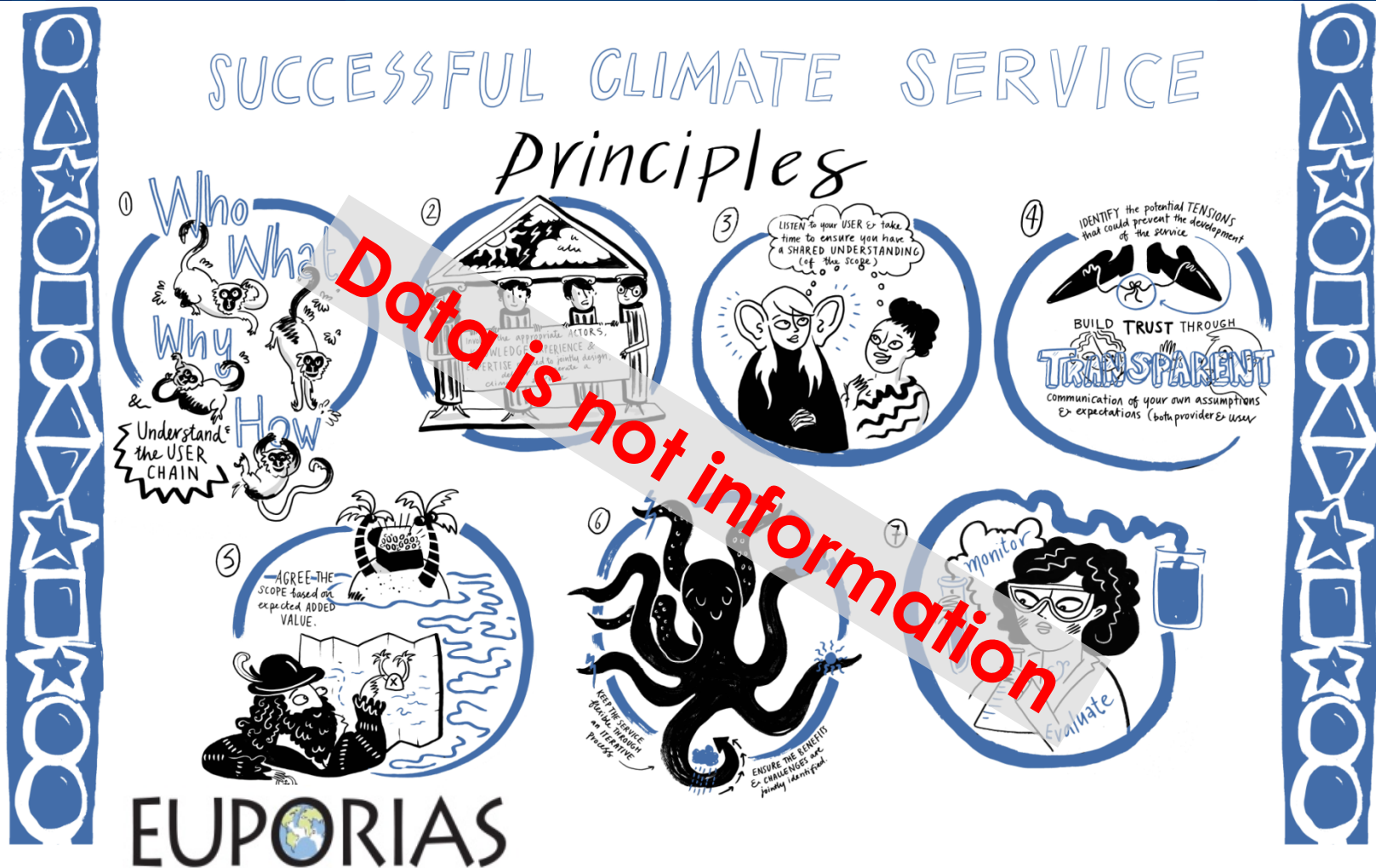- Predictions
- Projections

What are the societal impacts?
- Climate indicators
- Sectoral information

BSC-ES Ongoing projects:

- QA4Seas: Forecast quality assessment of climate predictions.

- MAGIC: Evaluation of historical climate simulations

- SECTEUR: Climate indicators for the public sector
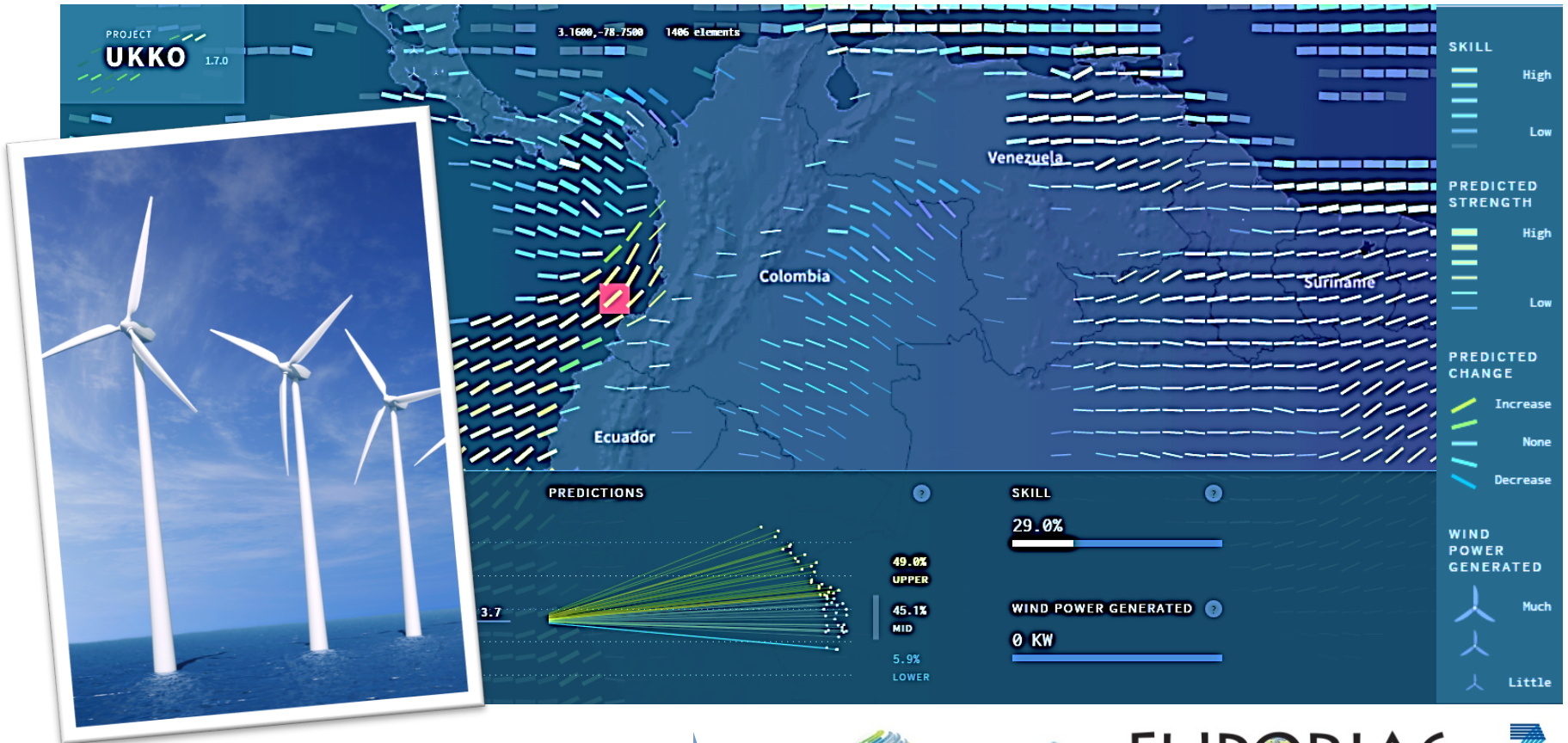
Extreme event attribution not yet part

Ethical Framework for Climate Services four core elements: integrity, transparency, humility and collaboration.
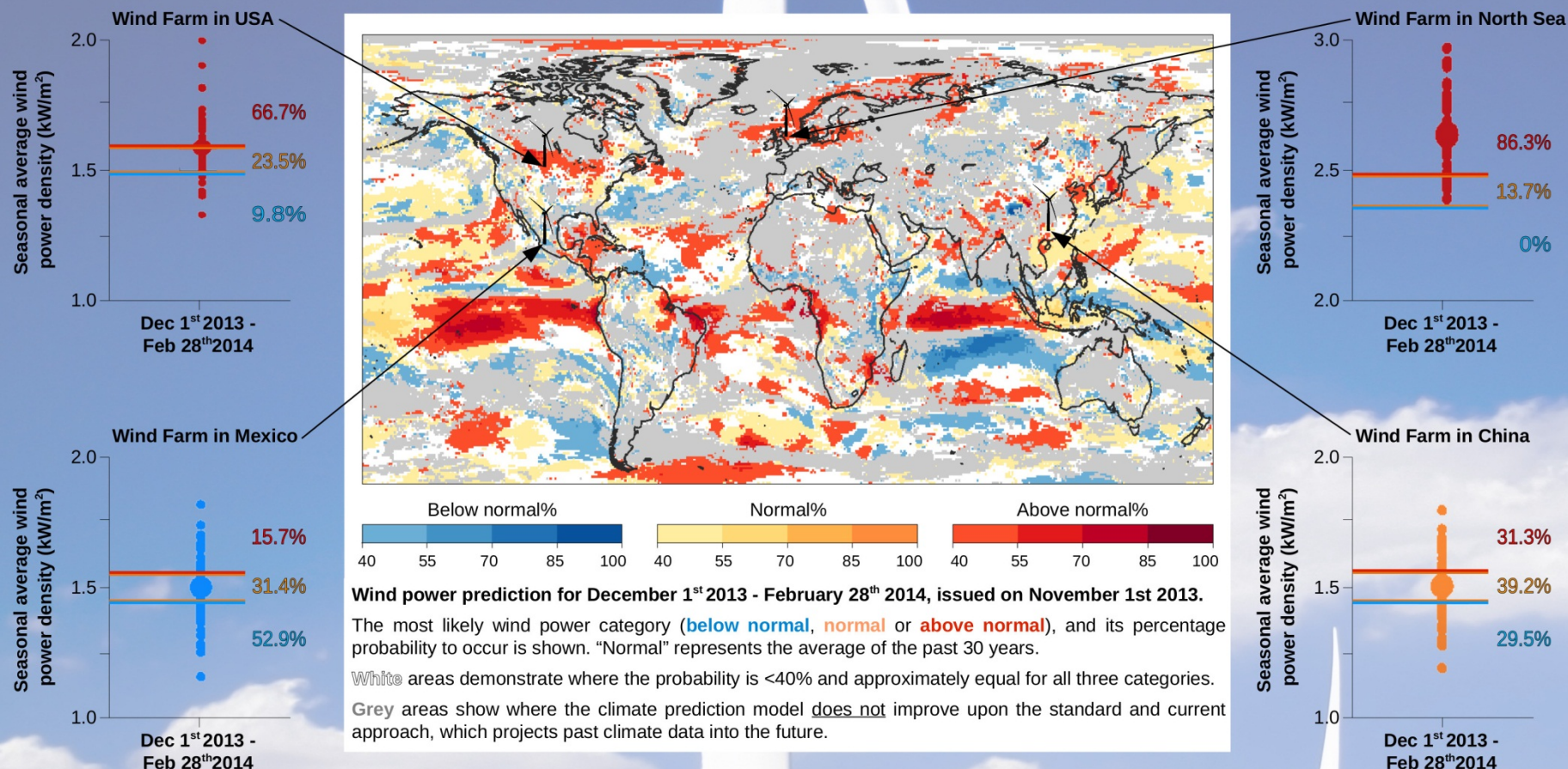
Seasonal wind power predictions

Climate data for wind energy

Illustrative examples of seasonal wind power predictions

First comprehensive service of predictions of tropical cyclone seasonal frequency. www.seasonalhurricanepredictions.org

Bodegas Torres (a Spanish winery) is looking for new locations for its vineyards (and it's not the only one doing it).
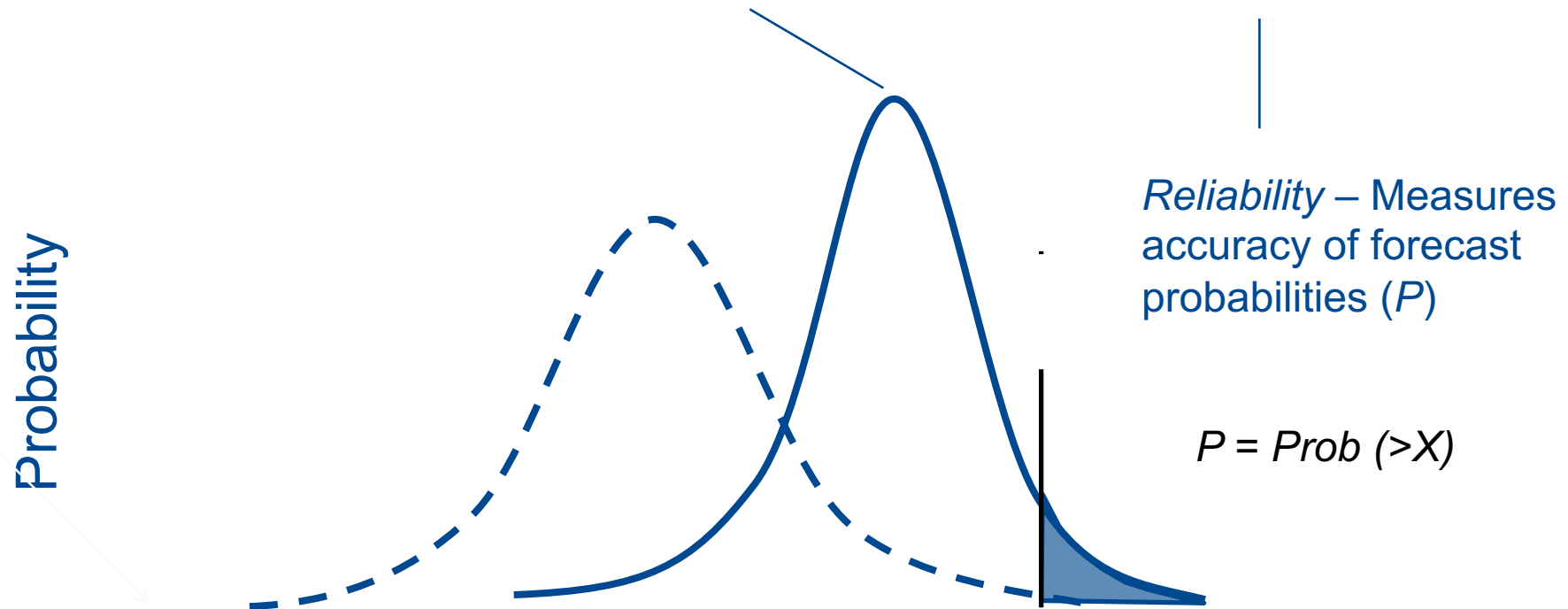
Land is being purchased closer to the Pyrenees, at higher elevation. They are considering acquiring land in South America too, in areas where wine is currently not produced.

Bodegas Torres requests local climate information (including appropriate uncertainty assessments) for the vegetative cycle of the vine, which lasts 30-40 years.

Where we are heading to

- **Improve our forecast systems** with better land use estimates, data assimilation (better use of the existing observations), high resolution, ensembles, better knowledge of the physical processes, etc.

- Address **services for specific users**: renewable energy, health, transport, agriculture, etc.

- **Visualization and dissemination** of predictions of air quality, weather and climate using international standards; influence those standards.

- Foster **open research** (both data and knowledge).

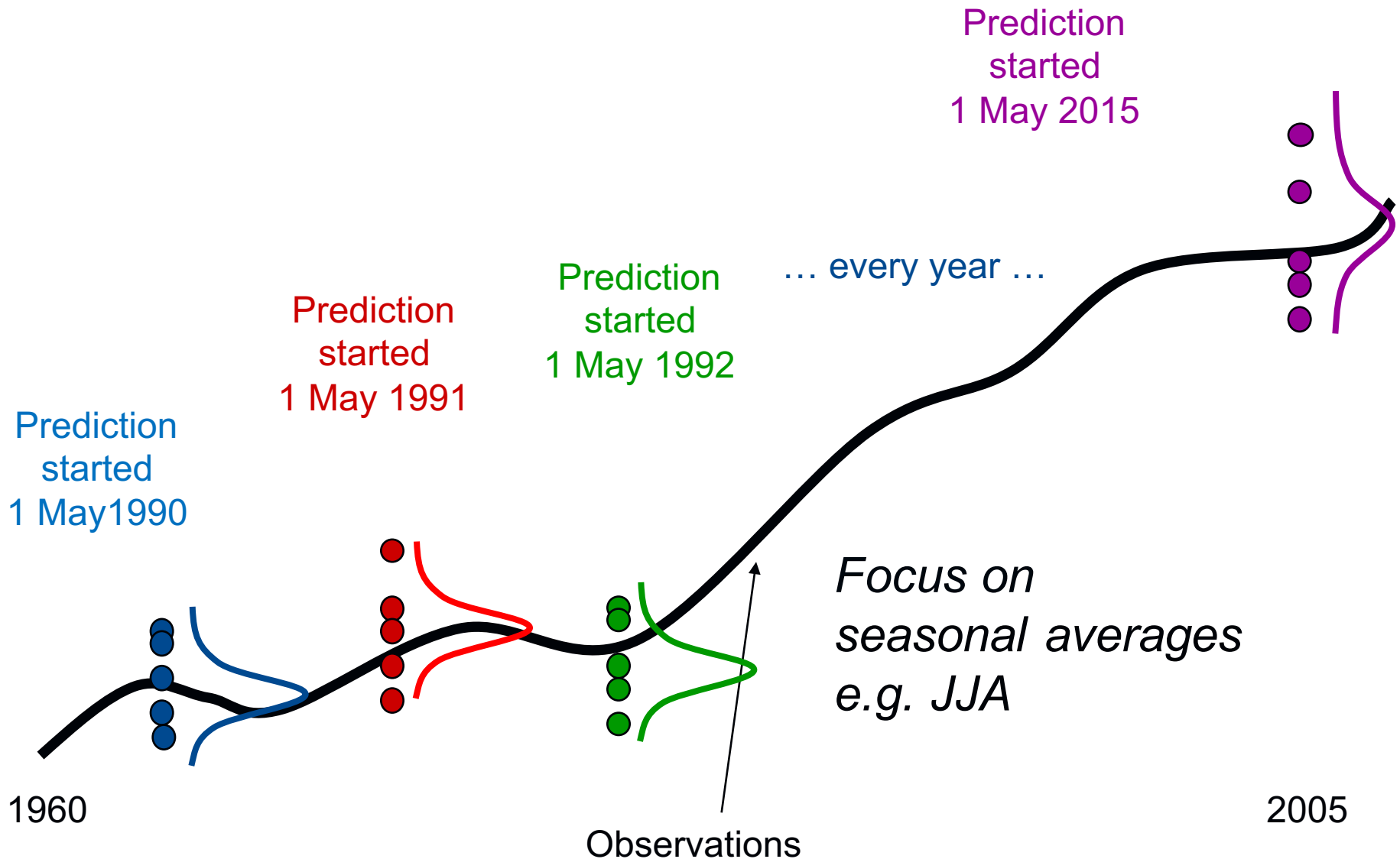How accurate is the ensemble mean and the distribution ?

Reliability – Measures accuracy of forecast probabilities (*P*)

P = Prob (>X)

Probability

e.g. agricultural threshold or extreme event

Prediction started 1 May 2015

Prediction started 1 May 1992

Prediction started 1 May 1991

Prediction started 1 May1990

… every year …

Focus on seasonal averages e.g. JJA

Observations

1960

2005

Profiling and Optimization

- Provide HPC Services
- Apply new computational methods

Software Development

- Development of HPC user-friendly software framework
- Support the development of atmospheric research software

Data Management

- Big Data in Earth Sciences
- Provision of data services

Make the most of the expertise in data and computational technologies at BSC

How accurate are extreme probability estimates from models?

Probabilities can be calibrated using observations of the past

P_2

P_1
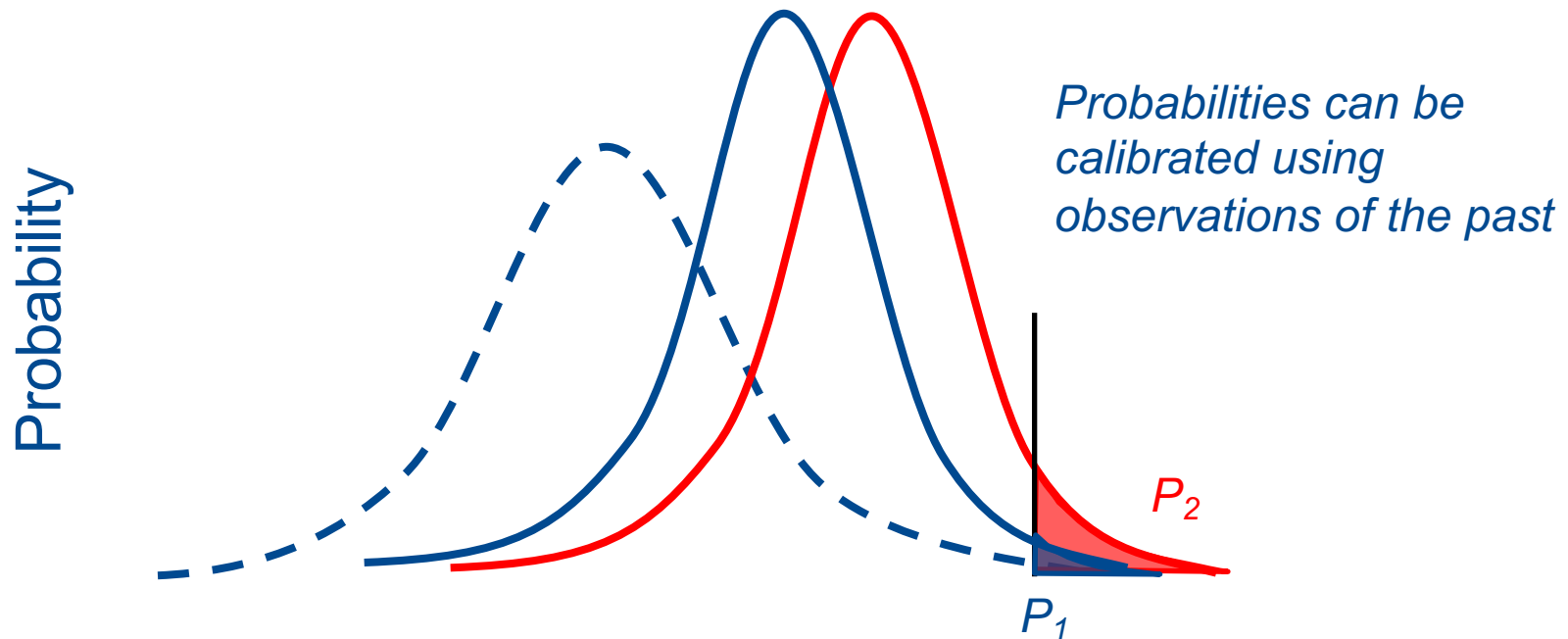
How man can we trust P_1 and P_2 ?

Climate models ensembles tend to be overconfident, ensemble calibration often leads to a reduction in attributable risk.
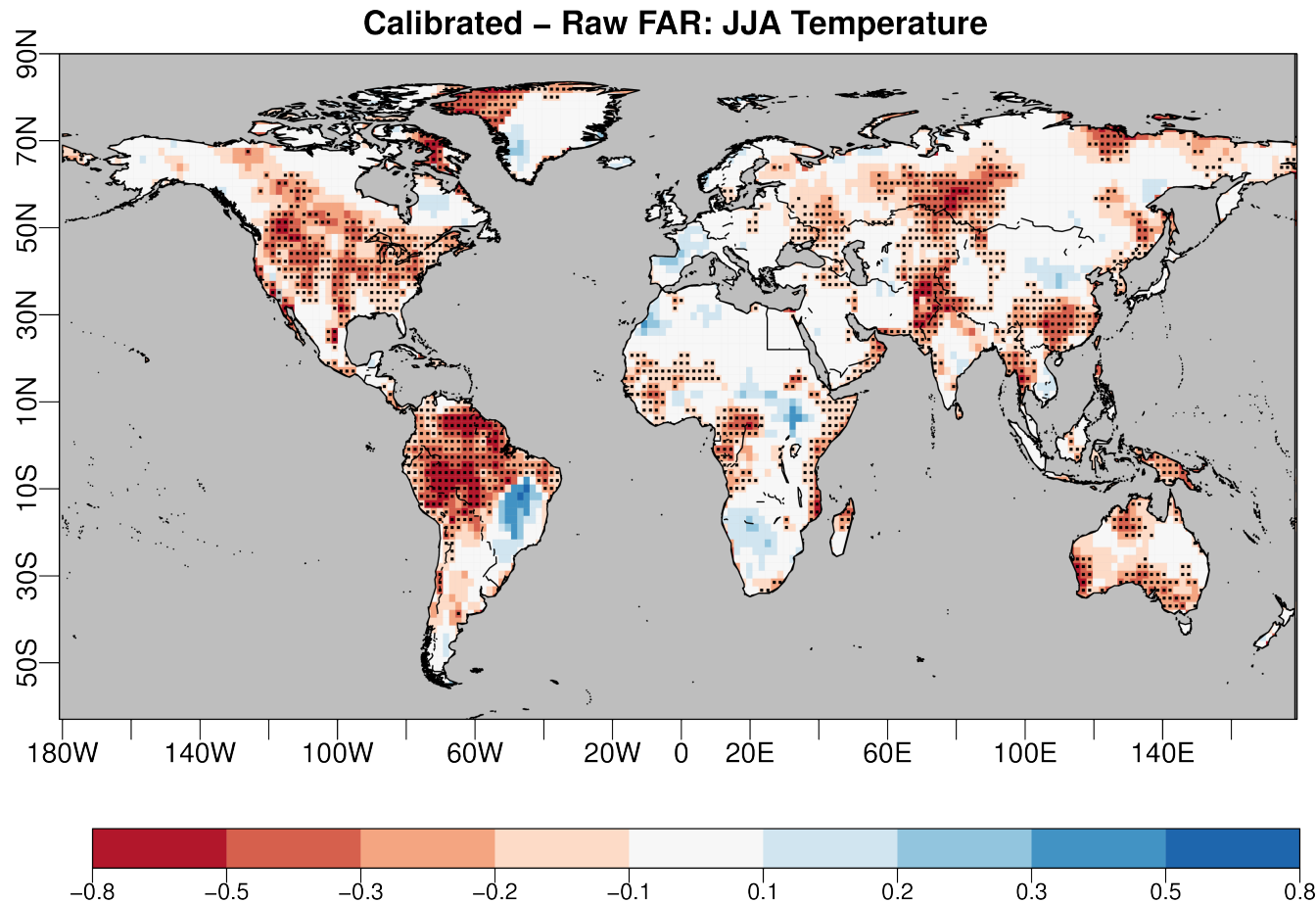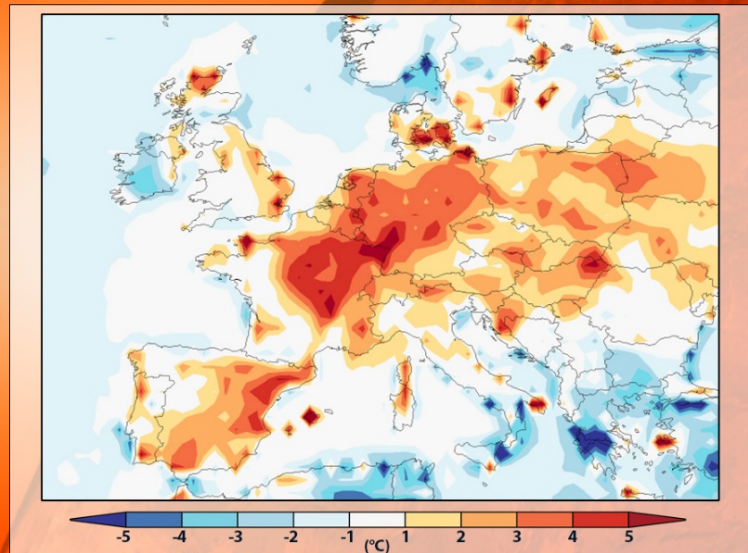

Calibrated – Raw FAR: JJA Temperature

Last years European heat wave has become twice as likely.
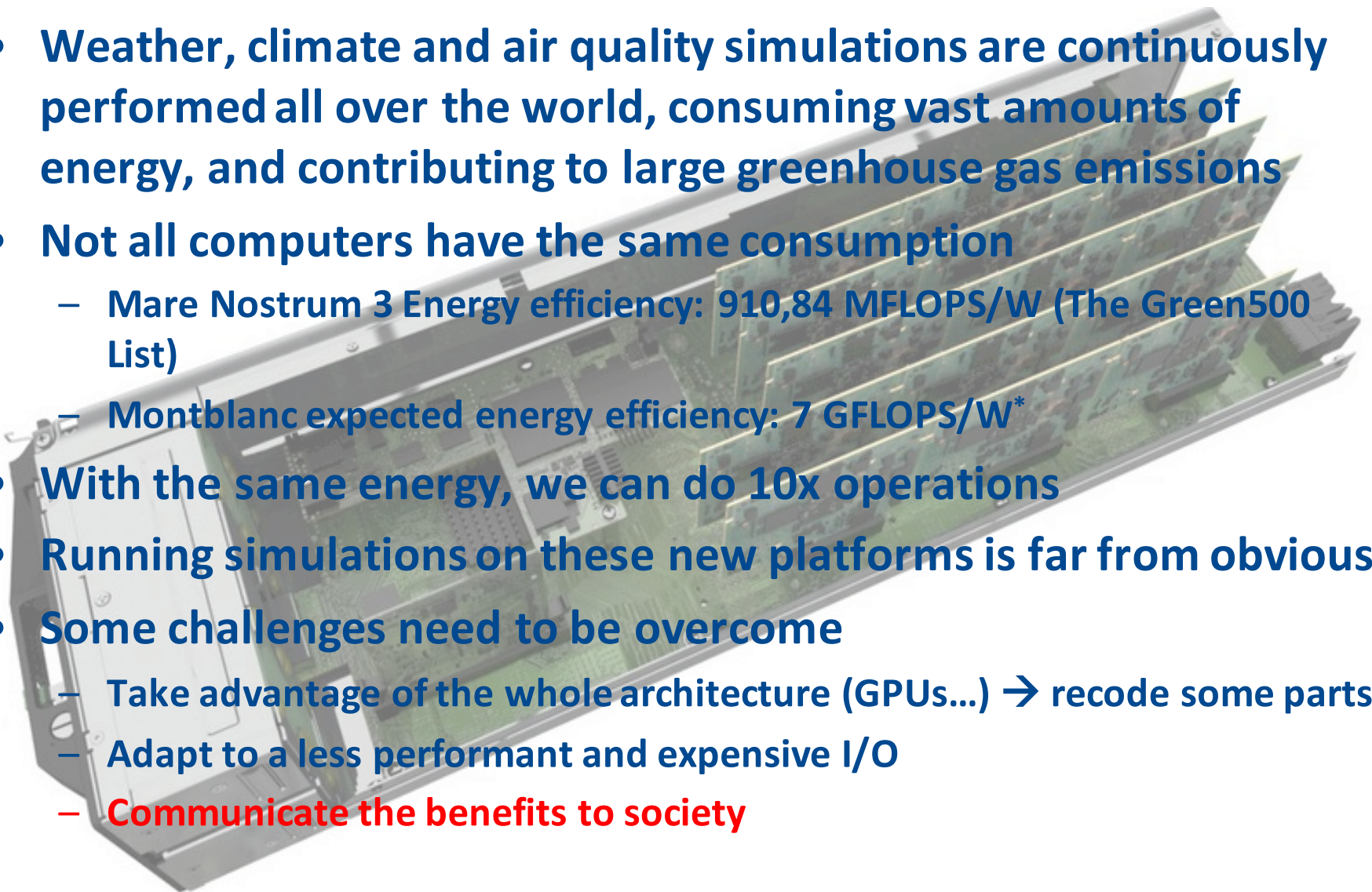
Prediction skill systematically higher in ESA CCI – Observational noise must be smaller compared to ERSST4

Massonet et al.
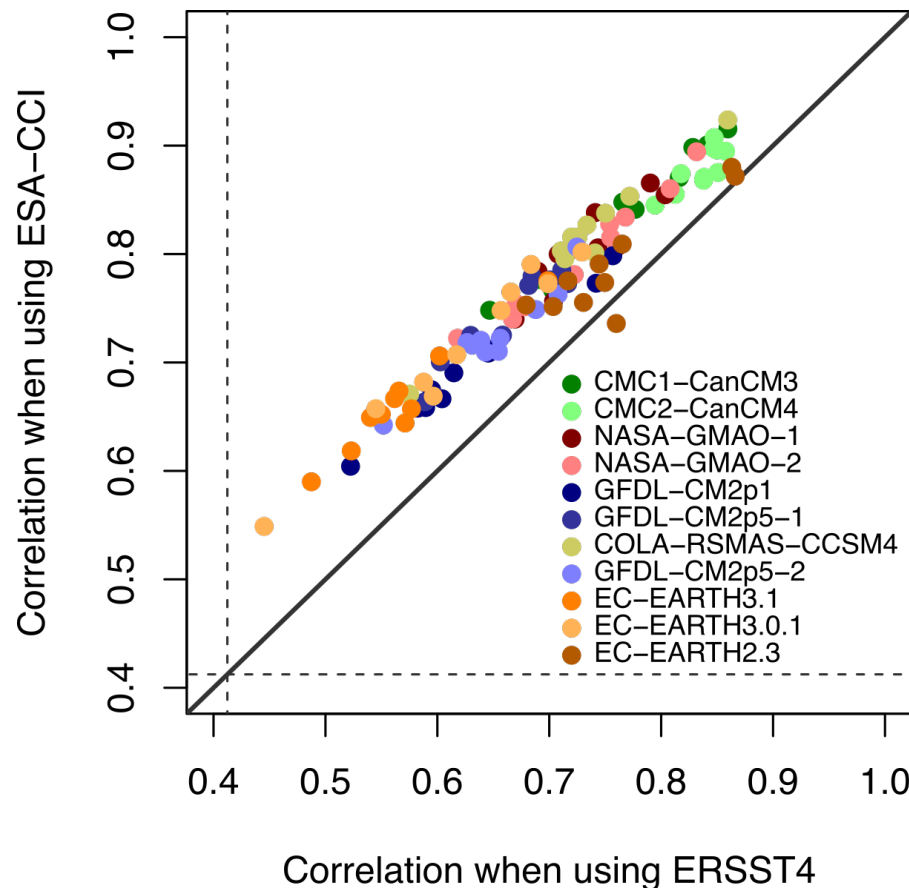
- **Weather, climate and air quality simulations are continuously performed all over the world, consuming vast amounts of energy, and contributing to large greenhouse gas emissions**
- **Not all computers have the same consumption**
  - **Mare Nostrum 3 Energy efficiency: 910,84 MFLOPS/W (The Green500 List)**
  - **Montblanc expected energy efficiency: 7 GFLOPS/W[*]**
- **With the same energy, we can do 10x operations**
- **Running simulations on these new platforms is far from obvious**
- **Some challenges need to be overcome**
  - **Take advantage of the whole architecture (GPUs…) → recode some parts**
  - **Adapt to a less performant and expensive I/O**
  - **Communicate the benefits to society**

* http://www.exascale.org/mediawiki/images/6/6b/Talk11-Ramirez.pdf